

# SEMILEPTONIC DECAYS OF BOTTOM AND CHARM BARYONS WITHIN RELATIVISTIC QUARK MODEL

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The results for observables of semileptonic decays of bottom and charm baryons (Isgur-Wise functions, decay rates, distributions, asymmetry parameters) are given within relativistic quark model. A comparison with recent experimental data (CLEO Collaboration) is made.

## 1 Introduction

The last few years have brought rapid development of the physics of hadrons composed of light quarks  $q$  ( $u$ ,  $d$  and  $s$ ) and heavy quarks  $Q$  ( $c$  or  $b$ ). Heavy quarks are those whose masses satisfy the condition  $m_Q \gg \Lambda_{QCD}$ , where  $\Lambda_{QCD}$  is the QCD scale parameter. Weak decays of heavy hadrons are a unique tool for determining the elements of the Cabibbo-Kobayashi-Maskawa matrix, for studying phenomena lying outside the scope of the standard model, and also for studying the internal structure of hadrons.

From the theoretical point of view, this lively interest in weak decays of heavy hadrons is mainly due to the discovery of a new type of spin-flavor symmetry in the world of heavy quarks (the Isgur-Wise symmetry)<sup>1,2</sup> and to the development of the Heavy Quark Effective Theory (HQET)<sup>1-8</sup> for studying of heavy-hadron weak decays. The Isgur-Wise symmetry (IWS) is occurring in limit of infinite mass of  $b$  and  $c$  quarks - the heavy quark limit (HQL). The HQET is a perturbative computational scheme based on expansion of QCD-inspired effective Lagrangian in terms of inverse powers of the heavy quark mass.

The consequences of the IWS for weak decay form factors of hadrons containing a single heavy quark were worked out by Isgur and Wise<sup>1,2</sup>. It was founded that these form factors are expressed through four universal functions (Isgur-Wise functions) and satisfied to group relations. Unfortunately, possibility to calculate  $\omega$ -dependence of IW-functions using Standard Model is absent. IW-functions are very sensitive to the effects of QCD at large distances, it cannot be calculated in perturbation theory. Only normalizations of these form factors at point  $\omega = 1$  are known. So calculation of IW-functions got dissemination within various phenomenological approaches: QCD Sum Rules, QCD on Lattice, Infinite Momentum Frame models, Quark Confinement Model, Bag models and etc.

Our purpose is to describe observables of semileptonic decays of bottom and charm baryons in the HQL within relativistic quark model. This approach allows to take account long-distance effects of QCD interactions. We shall calculate baryonic Isgur-Wise functions and charge radii, decay rates and asymmetry parameters. Also detailed description of  $\Lambda_c^+ \rightarrow \Lambda + e^+ + \nu_e$  decay which was measured recently by CLEO Collaboration<sup>9</sup> will be given.

## 2 Model

In our model<sup>10</sup> baryons are considered as bound states of valence quarks. Annihilation of baryons into quarks and *vice versa* are described by means of the corresponding interaction Lagrangian.

$$\mathcal{L}_{int}(x) = g_B \bar{B}(x) J_B(x) + h.c. \quad (1)$$

where  $B$  is a baryon field,  $J_B$  is a three-quark current,  $g_B$  is a coupling constant. A distribution of quarks in baryon is taken account by corresponding relativistic vertex form factor  $F\left(\sum_{i<j}[y_i - y_j]^2\right)$ , where  $y_i (i = 1, 2, 3)$  are the space coordinates of quarks. The three-quark current  $J_B(x)$  is chosen in the form

$$J_B(x) = \int dy_1 \int dy_2 \int dy_3 \delta\left(x - \frac{\sum_i m_i y_i}{\sum_i m_i}\right) F\left(\sum_{i<j}[y_i - y_j]^2\right) \times q^{a_1}(y_1) q^{a_2}(y_2) q^{a_3}(y_3) \varepsilon^{a_1 a_2 a_3} \quad (2)$$

where the center of mass frame is used. Here spin and flavor indices are omitted. It is easy to see that in the limit

$$F\left(\sum_{i<j}[y_i - y_j]^2\right) \rightarrow \prod_{i<j} \delta(y_i - y_j)$$

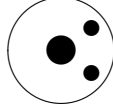
the baryonic current  $J_B(x)$  goes to

$$J_B(x) = q^{a_1}(x) q^{a_2}(x) q^{a_3}(x) \varepsilon^{a_1 a_2 a_3}$$

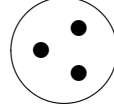
To say other words the interaction of quarks becomes local. The coordinates of quarks are connected with Jacobi coordinates  $\xi_1$  and  $\xi_2$  by standard manner

$$\begin{cases} y_1 = x - 3\xi_1(m_2 + m_3)/\sum_i m_i \\ y_2 = x + 3\xi_1 m_1/\sum_i m_i - 2\sqrt{3}\xi_2 m_3/(m_2 + m_3) \\ y_3 = x + 3\xi_1 m_1/\sum_i m_i + 2\sqrt{3}\xi_2 m_2/(m_2 + m_3) \end{cases}$$

For light baryons we apply the SU(3)-symmetric picture based on unitary symmetry in the light quark sector. For heavy-light baryons the heavy quark limit is used ( $m_Q \gg m_q$ ,  $m_Q \rightarrow \infty$ ). Hence heavy quark removes to the c.m. of heavy-light baryon. Therefore coordinates of quarks in heavy-light and light baryons look like this



Heavy-Light Baryon



Light Baryon



$$\begin{cases} y_Q = y_1 = x \\ y_{q_1} = y_2 = x + 3\xi_1 - \sqrt{3}\xi_2 \\ y_{q_2} = y_3 = x + 3\xi_1 + \sqrt{3}\xi_2 \\ \sum_{i < j} [y_i - y_j]^2 = 18(\xi_1^2 + \xi_2^2) \end{cases}$$



$$\begin{cases} y_{q_1} = y_1 = x - 2\xi_1 \\ y_{q_2} = y_2 = x + \xi_1 - \sqrt{3}\xi_2 \\ y_{q_3} = y_3 = x + \xi_1 + \sqrt{3}\xi_2 \\ \sum_{i < j} [y_i - y_j]^2 = 18(\xi_1^2 + \xi_2^2) \end{cases}$$

The form of vertex function  $F\left(\sum_{i < j} [y_i - y_j]^2\right)$  allows us to make all matrix elements ultraviolet finite. One has to underline that vertex functions can be understood as phenomenological taking account of long-distance effects of QCD interactions. In this point we follow the ideas of QCD-inspired models of hadrons<sup>11–13</sup> based on bilocal procedure of bosonization.

For light baryons with spin-parity  $J^P = \frac{1}{2}^+$  two independent forms of interaction Lagrangians exist (so-called *vector variant* and *tensor variant*)<sup>14</sup>

$$\begin{aligned} L_{int}^{light}(x) &= g_{B_q} \bar{B}^{mn}(x) \int d\xi_1 \int d\xi_2 f(\xi_1^2 + \xi_2^2) \Gamma_1 \lambda_f^{nk_1} q_{k_1}^a(x - 2\xi_1) \\ &\times q_{k_2}^b(x + \xi_1 - \sqrt{3}\xi_2) C \Gamma_2 \lambda_f^{kk_3} q_{k_3}^c(x + \xi_1 + \sqrt{3}\xi_2) \varepsilon^{abc} \varepsilon^{mk_2k} + h.c. \end{aligned}$$

$$B = \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda^0 & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda^0 & n \\ -\Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda^0 \end{pmatrix} \text{ baryon matrix}$$

$$q_j^a = \begin{pmatrix} u^a \\ d^a \\ s^a \end{pmatrix} \text{ set of quark fields}$$

$$\Gamma_1 \otimes C\Gamma_2 = \begin{cases} \gamma^\mu \gamma^5 \otimes C\gamma_\mu & \text{vector variant} \\ \sigma^{\mu\nu} \gamma^5 \otimes C\sigma_{\mu\nu} & \text{tensor variant} \end{cases}$$

One has to remark that spin-flavor structure of our light baryon currents is identical to ones used in QCD Sum Rules by Ioffe et al.<sup>15</sup>

Choice of quark currents of heavy-light baryons was discussed firstly by Shuryak in ref.<sup>16</sup>. He has showed that for  $\Lambda$ -type baryons ( $\Lambda_Q$  or  $\Xi_Q$ ) containing a scalar light diquark three possibilities of baryonic currents exist

$$\begin{cases} J_{\Lambda_Q}^{(1)} = Q^a (u^b C \gamma^5 d^c) \varepsilon^{abc} & \text{scalar variant} \\ J_{\Lambda_Q}^{(2)} = \gamma_5 Q^a (u^b C d^c) \varepsilon^{abc} & \text{pseudoscalar variant} \\ J_{\Lambda_Q}^{(3)} = \gamma_\mu Q^a (u^b C \gamma^\mu \gamma^5 d^c) \varepsilon^{abc} & \text{axial variant} \end{cases}$$

and for  $\Omega$ -type baryons ( $\Omega_Q$ ,  $\Omega_Q^*$  or  $\Sigma_Q$ ,  $\Sigma_Q^*$ ) containing a vector light diquark two possibilities exist

$$\begin{cases} J_{\Omega_Q}^{(1)} = \gamma_\mu \gamma_5 Q^a (s^b C \gamma^\mu s^c) \varepsilon^{abc} & \text{vector variant} \\ J_{\Omega_Q}^{(2)} = \sigma_{\mu\nu} \gamma_5 Q^a (s^b C \sigma^{\mu\nu} s^c) \varepsilon^{abc} & \text{tensor variant} \end{cases}$$

$$\begin{cases} J_{\Omega_Q^*}^{\mu(1)} = Q^a (s^b C \gamma^\mu s^c) \varepsilon^{abc} & \text{vector variant} \\ J_{\Omega_Q^*}^{\mu(2)} = -i\gamma_\nu Q^a (s^b C \sigma^{\mu\nu} s^c) \varepsilon^{abc} & \text{tensor variant} \end{cases}$$

In our calculations we will use *tensor variant* for light pseudoscalar baryons, *scalar variant* for  $\Lambda$ -type baryons and *vector variant* for  $\Omega$ -type baryons. One

has to remark that *pseudoscalar variant* for  $\Lambda$ -type baryons doesn't give contribution at the HQL.

Matrix elements of semileptonic decays of heavy-light baryons are described in our model by triangle diagram (see, Fig.1). As the light quark propagator the standard free fermion propagator is used

$$S_q(k) = \frac{i(\not{k} + m_q)}{k^2 - m_q^2 + i\epsilon} \quad (3)$$

where  $m_q$  is the light quark mass which is a free parameter. As the heavy quark propagator we use propagator arising at the heavy quark limit (HQL)

$$S(k + v\bar{\Lambda}) = \frac{i(1 + \not{v})}{2(v \cdot k + \bar{\Lambda} + i\epsilon)} \quad (4)$$

where  $\bar{\Lambda}$  is the difference between masses of heavy baryon and heavy quark at the HQL,  $v$  is the four-velocity of heavy baryon.

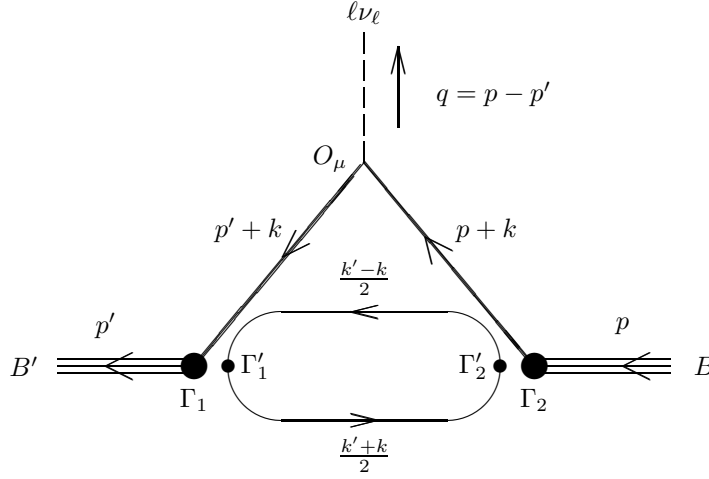


Fig. 1

Typical matrix element describing heavy-to-heavy transition is given by the following expression

$$\begin{aligned} \bar{u}(v') M_\Gamma(v, v') u(v) &= gg' \int \frac{d^4 k}{\pi^2 i} \int \frac{d^4 k'}{\pi^2 i} \text{Tr} \left[ \Gamma'_1 S_q \left( \frac{k' - k}{2} \right) \Gamma'_2 S_q \left( \frac{k' + k}{2} \right) \right] \\ &\times F^2 (9k^2 + 3k'^2) \bar{u}(v') \Gamma_1 S(k + v'\bar{\Lambda}) \Gamma S(k + v\bar{\Lambda}) \Gamma_2 u(v) \end{aligned}$$

Here coupling constants  $g$  and  $g'$  are calculated by solving the equation:

$$Z_B = 1 - g^2 \Pi'_B(M_B) = 0$$

It is the so-called compositeness condition in quantum field theory, which coincides with the Ward identity between the derivative of baryon mass operator  $\Pi'_B$  and electromagnetic vertex function. It provides the correct normalization of baryonic IW-functions.

Now let us to discuss the choice of free parameters in our approach. There are three groups of free parameters in our model: light quark masses, the set of parameters  $\bar{\Lambda}$  and vertex functions.

For masses of  $u$  and  $d$  quarks the unit parameter is used:  $m_u = m_d = m_q$ , which is varied in the limits 310-340 MeV. The best fit  $m_q=315$  MeV comes from analysis of nucleon physics within our model. The strange quark mass  $m_s$  is varied in the limits 500-550 MeV. The best value for  $m_s=500$  MeV comes from analysis of  $\Lambda_c^+ \rightarrow \Lambda \ell^+ \nu_\ell$  decay. The values of parameters  $\bar{\Lambda}$  must depend on the flavor of light diquark. We suggest that  $\bar{\Lambda}$  must be little than the sum of light quark masses:  $\bar{\Lambda} < m_{q_1} + m_{q_2}$ . This constraint provides the absence of singularities in the matrix elements connected with production of free quarks. Finally, we use  $\bar{\Lambda} = 600$  MeV for heavy-light baryon without strange quark,  $\bar{\Lambda} = 800$  MeV for heavy-light baryon containing a single strange quark and  $\bar{\Lambda} = 950$  MeV for heavy-light baryon containing two strange quarks. For simplicity, the Gaussian form of vertex functions is used

$$F(\xi_1^2 + \xi_2^2) = \frac{\Lambda^4}{(16\pi^2)} \exp\left([\xi_1^2 + \xi_2^2] \frac{\Lambda^2}{4}\right)$$

where  $\Lambda$  is a cutoff parameter. The parameters  $\Lambda$  must be different for light and heavy-light (h.-l.) baryons. The value of  $\Lambda$  for light baryons was fixed in the analysis of nucleon properties:  $\Lambda_{light}=2.885$  GeV. The value of  $\Lambda_{h.-l.} = 1.909$  GeV was found in the analysis of  $\Lambda_c^+ \rightarrow \Lambda \ell^+ \nu_\ell$  process.

### 3 Results

In this Section we focus on the results of our calculations. We present the predictions for the  $b \rightarrow c$  semileptonic decays. IW-functions, decay rates and asymmetry parameters in two-cascade decay  $\Lambda_b^0 \rightarrow \Lambda_c^+ [\rightarrow \Lambda \pi^+] + W^- [\rightarrow \ell^- \bar{\nu}_\ell]$  are calculated. Also heavy-to-light flavor exchange decays are considered. The detailed description of the  $\Lambda_c^+ \rightarrow \Lambda + e^+ + \nu_e$  decay which was recently measured by CLEO Collaboration<sup>9</sup> is given. Here the following values for CKM matrix elements are used:

$$|V_{bc}| = 0.044, |V_{cs}| = 1, |V_{cd}| = 0.204, |V_{bu}| = 0.002 \div 0.005$$

### 3.1 Isgur-Wise functions

It is well-known, that weak baryonic currents for  $b \rightarrow c$  transitions are expressed through the three universal Isgur-Wise functions  $\zeta, \xi_1, \xi_2$  at the HQL.

- $\Lambda_b \rightarrow \Lambda_c$  Transition

$$\langle \Lambda_c(v') | \bar{c} \Gamma b | \Lambda_b(v) \rangle = \zeta(\omega) \bar{u}_{\Lambda_c}(v') \Gamma u_{\Lambda_b}(v)$$

- $\Omega_b \rightarrow \Omega_c(\Omega_c^*)$  Transition

$$\langle \Omega_c(v') \text{ or } \Omega_c^*(v') | \bar{c} \Gamma b | \Omega_b(v) \rangle = \bar{B}_c^\mu(v') \Gamma B_b^\nu(v) [-\xi_1(\omega) g_{\mu\nu} + \xi_2(\omega) v_\mu v_\nu]$$

$$B_Q^\mu(v) = \frac{\gamma^\mu + v^\mu}{\sqrt{3}} u_{\Omega_Q}(v), \quad B_Q^\mu(v) = u_{\Omega_Q^*}^\mu(v)$$

In our model IW-functions are expressed through the three structure integrals  $\Phi_i, i = 0, 1, 2$

$$\zeta(\omega) = \frac{\Phi_0(\omega)}{\Phi_0(1)}, \quad \xi_1(\omega) = \frac{\Phi_1(\omega)}{\Phi_1(1)}, \quad \xi_2(\omega) = \frac{\Phi_2(\omega)}{\Phi_1(1)}$$

$$\begin{aligned} \Phi_I(\omega) &= \int_0^\infty dx x \int_0^\infty \frac{dy y}{(y+1)^2} \int_0^1 d\phi \int_0^1 d\theta R_I(\omega) \exp \left[ -4s \left( \mu_q^2 - \frac{\bar{\lambda}^2}{4} \right) \right] \\ &\times \exp \left[ -2x^2 s \phi(1-\phi)(\omega-1) - s(x-\bar{\lambda})^2 - \frac{4}{3} \mu_q^2 (1-2\theta)^2 \frac{y^2}{1+y} \right] \end{aligned}$$

where

$$R_0(\omega) = \mu_q^2 + \frac{1}{s(1+y)} + \frac{x^2 \beta}{4(1+y)^2} (1 + 2\phi(1-\phi)(\omega-1))$$

$$R_1(\omega) = \mu_q^2 + \frac{1}{2s(1+y)} + \frac{x^2 \beta}{4(1+y)^2} (1 + 2\phi(1-\phi)(\omega-1))$$

$$R_2(\omega) = \frac{x^2 \beta}{2(1+y)^2} \phi(1-\phi)$$

$$\beta = 1 + 2y + 4y^2\theta(1 - \theta), \quad s = \frac{2}{3} + \frac{\beta}{3(1 + y)}, \quad \mu_q = \frac{m_q}{\Lambda}, \quad \bar{\lambda} = \frac{\bar{\Lambda}}{\Lambda}$$

It is clear that functions  $\zeta$  and  $\xi_1$  have the correct normalization at zero recoil:  $\zeta(1) = 1$  and  $\xi_1(1) = 1$ .

Now let us to check the model-independent inequalities for form factors of  $\Omega_b$  decays derived by Xu<sup>17</sup>

$$1 \geq \frac{2 + \omega^2}{3} \xi_1^2(\omega) + \frac{(\omega^2 - 1)^2}{3} \xi_2^2(\omega) + \frac{2}{3}(\omega - \omega^3) \xi_1(\omega) \xi_2(\omega) \quad (5)$$

$$\rho_{\xi_1}^2 \geq \frac{1}{3} - \frac{2}{3} \xi_2(1) \quad (6)$$

Exploiting the expression for  $\xi_1(\omega)$  and  $\xi_2(\omega)$  functions we can proof that the inequality (6) for the slope of  $\xi_1$  function is fulfilled for any values of  $\omega$ . Also we obtain the low limit for the radius of  $\xi_1$  function

$$\rho_{\xi_1}^2 \geq 1/3$$

Additionally we find that function  $\xi_2(\omega)$  at point  $\omega = 1$  satisfies the condition  $0 < \xi_2(1) < 1/2$ .

There is more sophisticated situation with the inequality (5). For convenience, we rewrite this inequality in the form

$$1 \geq B(\omega) = \frac{1}{3} \xi_1^2(\omega) + \frac{2}{3} (\omega \xi_1(\omega) - \xi_2(\omega)(\omega^2 - 1))^2$$

We can show that the combination  $\omega \xi_1(\omega) - \xi_2(\omega)(\omega^2 - 1)$  satisfies to the following condition  $0 < \omega \xi_1(\omega) - \xi_2(\omega)(\omega^2 - 1) \leq \omega \xi_1(\omega)$ . Hence,

$$\frac{1}{3} \xi_1^2(\omega) < B(\omega) \leq \frac{1 + 2\omega^2}{3} \xi_1^2(\omega)$$

Thus the Bjorken-Xu inequality (5) gives us the upper limit for the function  $\xi_1(\omega)$ :

$$\xi_1 \leq \sqrt{\frac{3}{2\omega^2 + 1}}$$

Of course, free parameters of the model were chosen with taking into account of the last constraint.



On the Fig.2 the results for the IW-function  $\zeta$  are given. One can see, our result coincides with dipole fit result <sup>19</sup> and goes higher than results of IMF models <sup>18,19</sup>.

Also we calculate the radii of IW-functions  $\zeta$  and  $\xi_1$  which are defined as

$$\rho_F^2 = -F'(1), \quad F'(\omega) = \frac{dF(\omega)}{d\omega} \quad \text{where} \quad F = \zeta \quad \text{or} \quad \xi_1$$

The results for the charge radii are listed in Table 1. For comparison we remember the results for these quantities predicted by IMF model <sup>19</sup> and dipole model <sup>19</sup>.

Table 1. Radii of Isgur-Wise Functions

Model	$\rho_\zeta^2$	$\rho_{\xi_1}^2$
Our	1.70	1.74
Körner et al. <sup>19</sup>	3.04	-
Dipole Fit <sup>19</sup>	1.78	-

### 3.2 Decay Rates and Asymmetry Parameters

In the Table 2 the results for total and partial rates of  $\Lambda_b^0 \rightarrow \Lambda_c^+ + e^- + \bar{\nu}_e$  decay are given

Table 2. Rates of  $\Lambda_b^0 \rightarrow \Lambda_c^+ + e^- + \bar{\nu}_e$  Decay (in units  $10^{10} \text{ sec}^{-1}$ )

Approach	$\Gamma_{total}$	$\Gamma_T$	$\Gamma_{T+}$	$\Gamma_{T-}$	$\Gamma_L$	$\Gamma_{L+}$	$\Gamma_{L-}$
Our	5.66	2.19	0.56	1.63	3.47	0.13	3.34
Körner et al. <sup>19</sup>	3.71	1.58	0.43	1.15	3.13	0.10	2.03
Dipole Fit <sup>19</sup>	5.65	2.17	0.56	1.61	3.48	0.13	3.35

In Table 3 we give the predictions for the asymmetry parameters which characterize the two-cascade decay  $\Lambda_b^0 \rightarrow \Lambda_c^+[\rightarrow \Lambda\pi^+] + W^-[\rightarrow \ell^- \bar{\nu}_\ell]$

Table 3. Asymmetry Parameters of  $\Lambda_b^0 \rightarrow \Lambda_c^+[\rightarrow \Lambda\pi^+] + W^-[\rightarrow \ell^- \bar{\nu}_\ell]$  Decay.

Model	$\alpha$	$\alpha'$	$\alpha''$	$\gamma$	$\alpha_P$	$\gamma_P$
Our	-0.76	-0.12	-0.52	0.56	0.38	-0.17
Körner et al. <sup>19</sup>	-0.71	-0.12	-0.46	0.61	0.33	-0.19
Dipole Fit <sup>19</sup>	-0.75	-0.12	-0.51	0.57	0.37	-0.17

The results for rates of various modes of semileptonic decays of bottom and charm baryons are performed in Table 4.

Table 4. Semileptonic Decay Rates (in units  $10^{10} \text{ s}^{-1}$ ).

process	Ref. <sup>20</sup>	Ref. <sup>21</sup>	Ref. <sup>22</sup>	Our	Exp. <sup>23</sup>
$\Lambda_c^+ \rightarrow \Lambda^0 e^+ \nu_e$	9.8	7.1		6.21	$7.0 \pm 2.5$
$\Xi_c^0 \rightarrow \Xi^- e^+ \nu_e$	8.5	7.4		4.66	
$\Lambda_b^0 \rightarrow p e^- \nu_e$				$0.006 \div 0.034$	
$\Lambda_c^+ \rightarrow n e^+ \nu_e$				1.04	
$\Lambda_b^0 \rightarrow \Lambda_c^+ e^- \bar{\nu}_e$	5.9	5.1	5.14	5.66	
$\Xi_b^0 \rightarrow \Xi_c^+ e^- \bar{\nu}_e$	7.2	5.3	5.21	4.67	
$\Omega_b^- \rightarrow \Omega_c^0 e^- \bar{\nu}_e$	5.4	2.3	1.52	0.77	
$\Omega_b^- \rightarrow \Omega_c^{*0} e^- \bar{\nu}_e$			3.41	2.02	
$\Sigma_b^+ \rightarrow \Sigma_c^{++} e^- \bar{\nu}_e$	4.3			1.42	
$\Sigma_b^+ \rightarrow \Sigma_c^{*++} e^- \bar{\nu}_e$				3.26	

### 3.3 Decay $\Lambda_c^+ \rightarrow \Lambda + e^+ + \nu_e$

In this section we focus on the properties of the  $\Lambda_c^+ \rightarrow \Lambda + e^+ + \nu_e$  decay which was recently investigated by CLEO Collaboration<sup>9</sup>. At the HQL, when a mass of charm quark goes to infinity ( $m_C \rightarrow \infty$ ), weak hadronic current is defined by two form factors  $f_1$  and  $f_2$  as

$$\langle \Lambda(p') | \bar{s} O_\mu c | \Lambda_c(v) \rangle = \bar{u}_\Lambda(p') [f_1(p' \cdot v) + \not{p}' f_2(p' \cdot v)] O_\mu u_{\Lambda_c}(v)$$

In order to extract the form factor ratio  $R = f_2/f_1$  from the CLEO experiment<sup>9</sup> an assumption was made about the  $q^2$  dependence of the form factors  $f_1$  and  $f_2$ . Following the model of Körner and Krämer<sup>24</sup>, the identical dipole form of weak form factors was used. The same *ansatz* was used in the ref.<sup>21</sup>. In our model, the form factors  $f_1$  and  $f_2$  have the different  $q^2$  dependence. In Table 5 we give the results for ratio  $R$  obtained within our approach at maximum and zero recoils. You can see, that our predictions weakly deviate from experimental data<sup>9</sup> and result of Cheng and Tseng<sup>21</sup>. The momentum dependence of form factors ( $f_1$  and  $f_2$ ) and their ratio is drawn on Fig.3. Here we use the notation variable  $\omega = (p' \cdot v)/M_\Lambda$ , where  $M_\Lambda$  is the  $\Lambda$  baryon mass. We found that the variation of the value of  $R$  is small. Also, in Table 5, our results for rate of  $\Lambda_c^+ \rightarrow \Lambda + e^+ + \nu_e$  transition and for asymmetry parameter  $\alpha_{\Lambda_c}$  are given. They are in a good agreement with experimental data and result of model<sup>21</sup>.

Table 5. Properties of  $\Lambda_c^+ \rightarrow \Lambda + e^+ + \nu_e$  Decay

Value	Our	Ref. <sup>21</sup>	Exp. <sup>9,23</sup>
$\Gamma(\Lambda_c^+ \rightarrow \Lambda^0)$ in $10^{-10} \text{ s}^{-1}$	6.21	7.1	$7.0 \pm 2.5$
$\alpha_{\Lambda_c}$	-0.84		$-0.82^{+0.09+0.06}_{-0.06-0.03}$
$R = f_2/f_1$	-0.23 ( $q^2=q_{max}^2$ ) -0.18 ( $q^2=0$ )	-0.23 ( $q^2=q_{max}^2$ )	$-0.25 \pm 0.14 \pm 0.08$

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